INTERACTIVE COMPUTER SIMULATIONS FOR INTEGRATED LEARNING

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Abstract

Interactive, game-like simulators are emerging educational tools for industry and academia alike. As an example, the SimRefinery™ prototype (Fig. 1), a dynamic simulator of a petroleum refinery has been developed and tested in several education environments. In concept, SimRefinery™ is similar to the highly successful SimCity computer game produced by Maxis, Inc. This paper describes the prototype simulator, its development, and its implementation in industry (at Chevron) and in education (at the University of California, Davis).

Keywords

Computer games, simulators, computer instruction, refinery operations

Introduction

Imagine for a moment that you are in a classroom, seated in front of a computer monitor. On the screen is an aerial view of a refinery stretched out across a landscape (Fig. 2). The screen is alive - oil tankers are docking, railcars are pulling into the loading terminal, and vehicles are moving about.. Then, remembering your instructors suggestion, you reach for the mouse and click on the button labeled "crude unit" and learn that you are feeding 80,000 barrels of a light crude to the refinery. By clicking on the button labeled "operating margin report" you find out that your enterprise is losing $2 per barrel of crude oil processed, and that you're overproducing on regular gasoline. Worse yet, you can't sell the gasoline because it does not meet product specifications since the octane rating is too low!

You decide to lower the crude feed rate to correct the gasoline production. By adjusting the components blended into the gasoline you are able to just meet the octane requirements of your batch. You are now almost breaking even financially.

Now that the operation is running smoothly, you decide to explore. You click on the landscape over several of the processing units to find out details about their function and status. During your investigation, you suspect that the catalytic reformer unit is underutilized and decide to increase its "severity". This results in more octane for the pool. After adjusting the gasoline blending recipe you find you are now earning ten cents on the barrel.

Then unexpectedly, a flange fire is reported in the alkylation unit. The unit will be shut down for two shifts and, as a result, a main gasoline feedstock is suddenly unavailable. A hint button tells you that the incident was preventable had you appropriated more of the budget to training. It further adds that you could have continued production despite the fire if you had built up an inventory in the component tank.

Soon the class is over and you are amazed at how quickly the time flew. You save the status of the game to continue to explore and experiment tomorrow.

SimRefinery

The "game" described above is called SimRefinery™ and is adapted from the highly successful SimCity™ produced by Maxis Inc. SimRefinery™ is basically a dynamic, open ended *system simulation* which mimics the processes, their interactions and responses to present conditions. Besides refinery processes the simulation also integrates financial and marketing aspects, training, the environment, safety, labor , etc. Also, in certain circumstances, random events, such as fires or natural disasters, can occur in the refinery.

A prototype SimRefinery™ was developed by Chevron in cooperation with Maxis. The goals of the project were:

- to demonstrate the effective use of new computer technologies for training on complex systems/processes and for information transfer
- to replace current training materials which teach employees about what a refinery is
- to generate interest and ideas for other business simulations which would be of value to the company

Advantages

The narrative presented above shows many of the advantages of an interactive game-like simulator such as SimRefinery™ over traditional learning processes:

- The intuitive, graphical interface encourages learning by exploration and experimentation which is motivating to most people and accelerates learning.
- The "player" can use the learning mode most effective for him/her: exploring the help screens, analysis of the effects of changing operating conditions, or trial and error experimentation. Consequently, a larger group of trainees benefit from using this tool. It is reported that only 20% of the population learns well using the traditional, passive mode (lectures, books, etc.). Others (35%) learn more effectively through visual input (demonstrations, models), and the largest group (45%) learns best through experimentation (Schneider, 1990).
- The simulation teaches "systems thinking", covering interactions among diverse areas such as technology, labor, economics, the environment, R&D, and training. Harwit (1994) points out the drawbacks of "compartmentalization of knowledge in our educational system" which can lead to technical specialists who lack insight and knowledge about the real world.

SimRefinery Development

The design and development of a SimCity-like simulation requires a dedicated team of experts. The SimRefinery™ project team consisted of a refinery expert, two process engineers with software development backgrounds, a team of Maxis' software developers and a potential customer: an instructor enthusiastic about integrating SimRefinery™ in one of her classes at Chevron.

The learning design must be guided by a clear understanding of the way in which the end product will be used. The highly technical learning needs of refinery operators differ greatly from staff employees who need mainly to learn terminology and see the interdependencies of the organization.

Our objective was simply to develop a "generic" simulation whose main purpose was to demonstrate the advantages of SimCity-like simulations for training and education. The development of the prototype took 6 months. We estimate that a complete SimRefinery™ package can be developed in less than a year.

Implementation

Chevron

The SimRefinery™ prototype was demonstrated to management, training professionals and prospective trainees at Chevron. The response was exceedingly favorable, however, the next stage of development of SimRefinery™ has been delayed for several reasons:

- established training philosophies/approaches are hard to change,
- hardware has to be made available
- instructors need to be trained

- high development cost and limited market potential.

To assure the required level of technical accuracy and applicability for site-specific training in a high quality game-like simulator, a multidisciplinary development team is needed. As a result, the development cost is ~~very~~ high and the final product may not be of interest to the refining industry in general.

University of California at Davis

The SimRefinery™ prototype has been used at UC Davis for several purposes. It was adopted in ECH 1, Introduction to Chemical Engineering, a seminar course for first year students which provides an overview of the various subdisciplines of chemical engineering. Unlike previous seminars in ECH 1 which use overhead transparencies or traditional lecture styles of presentation, we used computer presentation software in conjunction with the simulator to teach the students about refining. The simulation was used to give students an overall view of what goes on in a refinery, very much like the walkthrough narrative described in the introduction. We had several objectives for the presentation:

- To familiarize students with a simplified overall flow diagram and the unit operations involved in refining
- To familiarize students with terminology used in the oil refining industry
- To point out the interdependencies between the technical aspects of the process, economics, market demands, quality specifications, safety etc.
- To challenge the students to explore SimRefinery™ on their own (the program was available on campus in computer laboratories and disks were distributed to interested students) to try to improve operation. A "challenge problem" was defined (with a copy of SimCity as the prize for the winner) to encourage students to further explore SimRefinery.

As expected, SimRefinery™ facilitated the introduction to oil refining tremendously. It is safe to say that it would be impossible to cover the subject any other way as clearly in the allotted time (50 min.). In course evaluations students stated that the simulator was fun to use, encouraged their interest in the chemical engineering profession and increased their understanding of refinery processes.

Although only a few of the students completed the "challenge problem", a significant fraction did explore SimRefinery™ on their own. Since ECH 1 is graded on a pass/not passed basis and students are normally taking a heavy load of coursework, it is not surprising that only a few of the most enthusiastic students completed the challenge problem. Further refinements to make the simulator easier to use (e.g. faster on networks in computer classrooms), and more complete would make it more effective as a teaching tool.

SimRefinery™ has also been used at UC Davis to provide prospective students with a glimpse of what chemical engineers do. SimRefinery™ was demonstrated to visiting high school students interested in majoring in chemical engineering. It was also demonstrated on Picnic Day, the annual "open house" for the UC Davis campus, where students, families, alumni and the general public visit the campus to learn more about the campus, activities, and various departments. In both cases, SimRefinery™ proved to be a very useful, exciting and fun way to show people with a variety of different backgrounds and levels of technical understanding about what goes on in a refinery.

The Future

Chevron is actively trying to bring together the right combination of people to further develop SimRefinery. Proposals under consideration at Chevron are to join with other industry sources.

The use of game-like simulators for higher education, particularly manufacturing, is very promising. With initial funding from the Teaching Resources Center at UC Davis and the UNOCAL Foundation, we plan to:

- Develop a new, more complete SimRefinery™ module to be used in an introductory course (ECH 1: Introduction to Chemical Engineering) and an upper division course (ECH 158A: Chemical Engineering Economics and Optimization) for Chemical engineering students. Not only will it provide students with a realistic overview of how a refinery works but it will also teach engineering students, at an early stage in their career, that technical issues are not the only ones that dictate the overall profitability of complex manufacturing processes but that issues such as environmental regulations, equipment maintenance, scheduling, market economics etc. have a significant impact as well.
- Develop a new General Education course for nonscience students on Issues and Options in Manufacturing which uses the refinery simulator. The objective of the course is to bridge the gap between scientists/engineers and students in the humanities/liberal arts. For nonscience students the course will provide a better understanding of the

technical aspects of a manufacturing plant (using the refinery as an example throughout the course) as well as the tradeoffs involved in meeting competing objectives. For science/engineering students the course will provide an integrated view of manufacturing in its societal context.

The potential impact of this educational project is very broad. First of all, the simulator modules and course designs can easily be transferred to other universities for use in courses similar to the ones we have described above. Secondly, it could be a model for development of new modules for other industries such as SimChemical (chemical plant), SimBiotech (a biotechnology plant), SimChip (this could be either integrated circuit manufacturing or potato chip production, depending on the target audience) etc. We are currently evaluating existing development software which would allow faculty to develop their own modules for their classes. In addition, the modules may be useful at lower levels, such as in high schools. Finally, further extensions using multimedia could make these teaching tools even more effective.

Summary

During the last five years simulator-based computer games have become very popular. An example is SimCity, developed by Maxis Inc. in 1989. The SimRefinery™ prototype is an adaptation of SimCity built initially to test the effectiveness of these types of simulators as teaching/training tools for industry. More recently, SimRefinery™ has been introduced into university courses.

The development of a prototype SimRefinery, modeled after SimCity, and its introductory use in industry and academia have taught us that

- Simulators significantly improve the learning process and facilitate teaching about complex systems. They accommodate diverse learning styles and thus reach more people. The interactive nature of the simulators generates excitement and a desire to explore further, all without financial or operating risk. Students gain a hands-on feel for the issues and variables affecting the refining business.
- The technology for developing these simulations is readily available.
- As is true for any delivery system, the learning design is the major part and challenge of the development project.
- Implementation needs a new educational paradigm. Without this, there are barriers for the introduction of these simulators.

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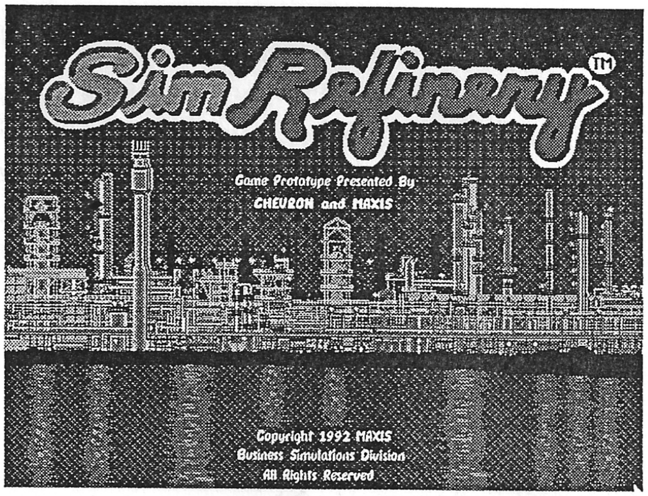

Figure 1. SimRefinery™ title screen

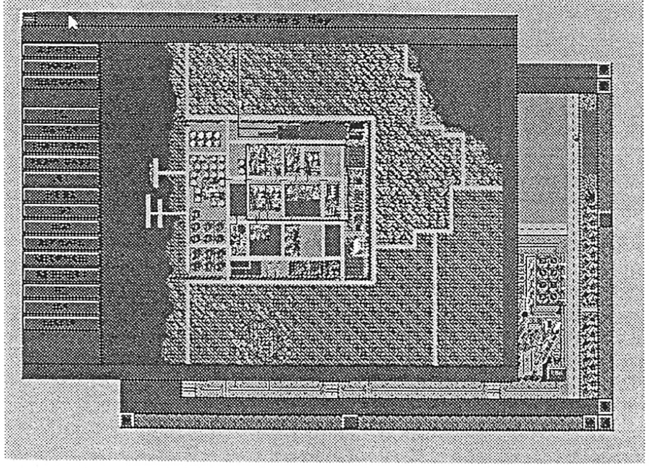

Figure 2. Aerial view of the refinery